

PLANT ITEM MATERIAL SELECTION DATA SHEET



FEP-SEP-00001A/B (PTF)

Waste Feed Evaporator Separator Vessels

- Design Temperature (max/min) (°F): 175/49
- Design Pressure (psig) (internal/external): 50/14.7
- Location: incell

ISSUED BY
RPP-WTP PDC

Contents of this document are Dangerous Waste Permit affecting

Operating conditions are as stated on sheets 5 and 6

Cannot be maintained nor replaced during the 40 y design life. No method of totally removing solids or heels is present.

Operating Modes Considered:

- The vessel is always alkaline, pH 13, at the normal operating temperature.
- The vessel will be cleaned using 2 N HNO₃ with residual chlorides and fluorides at normal operating temperatures; the condition of high temperature and acid is not examined.

Materials Considered:

Material (UNS No.)	Relative Cost	Acceptable Material	Unacceptable Material
Carbon Steel	0.23		X
304L (S30403)	1.00	X	
316L (S31603)	1.18	X	
6% Mo (N08367/N08926)	7.64	X	
Alloy 22 (N06022)	11.4	X	
Ti-2 (R50400)	10.1		X

Recommended Material: 304 (max 0.030% C; dual certified)

Recommended Corrosion Allowance: 0.04 inch (includes 0.00 inch erosion allowance)

Process & Operations Limitations:

- Develop rinsing/flushing procedure for acid and water



EXPIRES: 12/07/05

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This bound document contains a total of 6 sheets.

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PLANT ITEM MATERIAL SELECTION DATA SHEET

Corrosion Considerations:

a General Corrosion

Hammer's data (1981) lists a corrosion rate for 304 (and 304L) in NaOH of less than 20 mpy (500 $\mu\text{m/y}$) at 77°F and over 20 mpy at 122°F. He shows 316 (and 316L) has a rate of less than 2 mpy up to 122°F and 50% NaOH. Sedriks (1996) states that the 300 series stainless steels are acceptable in up to 50% NaOH at temperatures up to about 122°F or slightly above. Work with simulated-radwaste evaporators, six months at 140°F, showed 304L was slightly more resistant to corrosion (<0.2 mpy) than was 316L (<0.6 mpy). Ni 200, pure nickel, was much less resistant (≈ 7 mpy) probably due to the complexants present in the waste.

Davis (1994) states the corrosion rate for 304L in pure NaOH will be less than about 1 mpy up to about 212°F though Sedriks states the data beyond about 122°F are incorrect. Danielson & Pitman (2000), based on short term studies, suggest a corrosion rate of about 0.5 mpy for 316L in simulated waste at boiling, >212°F.

In review of the 242-A Evaporator in waste similar to that expected in LAW, it was found that the corrosion of 304L after about two years of operation at 140°F was less than the accepted variability of the plate. Because of uncertainties in the starting thickness of the metal, a review of the raw data was inconclusive.

Uhlig (1948) has shown that pure nickel is resistant to corrosion by NaOH. However, the presence of complexing agents may reverse the trend. Agarwal (2000) states that the higher nickel alloys are highly corrosion resistant though specific mention of alkaline media is not made. The general literature mainly discusses cracking problems (see below) rather than uniform corrosion.

The Savannah River evaporator vessels are made of 304L and have suffered no failures in about 30 years.

Conclusion:

Based on uniform corrosion and operating within the defined temperature limits, Savannah River experience and the testing, 304L would be satisfactory.

b Pitting Corrosion

Chloride is notorious for causing pitting in acid and neutral solutions. It is thought that in alkaline solutions, pH>12, chlorides are likely to promote pitting only in tight crevices. Koch (1995) is of the opinion that fluoride will have little effect.

Revie (2000) and Uhlig (1948) note that nitrate inhibits chloride corrosion. Therefore the high nitrate concentrations in the LAW are expected to be beneficial.

The apparent lack of pitting in the 242-A Evaporator suggests 304L is acceptable at the design conditions. Other studies confirm the good behavior of 304L when it is not a heat transfer surface; the SRS evaporator shell has been in existence for over 30 years.

Rinsing is expected to be sufficiently infrequent as to mandate the better operational behavior of 304L compared to 316L.

Conclusion:

Localized corrosion appears to be relatively minor in alkaline solutions except under heat transfer conditions or where deposits can form. As long as the temperatures remain in the normal operating range, $\leq 140^\circ\text{F}$ and the surfaces are not used for heat transfer, 304L is satisfactory.

c End Grain Corrosion

End grain corrosion only occurs in metal with exposed end grains and in highly oxidizing acid conditions.

Conclusion: Not applicable to this system.

d Stress Corrosion Cracking

The exact amount of chloride required to stress corrosion crack stainless steel is unknown. In part this is because the amount varies with temperature, metal sensitization, and the environment. But it is also unknown because chloride tends to concentrate under heat transfer conditions, by evaporation, and electrochemically during a corrosion process. Hence, even as little as 10 ppm can lead to cracking under some conditions. Generally, as seen in Sedriks (1996) and Davis (1987), stress corrosion cracking does not usually occur below about 140°F. Further, the use of "L" grade stainless reduces the opportunity for sensitization. From the above references, it also observed that alkaline conditions reduce the probability of the initiation of stress corrosion cracking to essentially zero. However, should a pit or crevice, including a deposit, be present where the environment can become acid, then the alkaline environment will no longer have an effect.

Caustic cracking tends to occur above 140 °F according to Sedriks or above 212 °F according to other work. Because the maximum operating temperature is < 140°F, all sources suggest caustic cracking should be minimal. Data from the Savannah River Site evaporators suggests cracking is not a concern in waste even to the design temperature.

Conclusion:

The use of 304L is expected to be acceptable for the vessel during operation.

e Crevice Corrosion

The comments on Pitting are equally valid here.

Conclusion:

The Pitting conclusions are valid.

PLANT ITEM MATERIAL SELECTION DATA SHEET**f Corrosion at Welds**

Weld corrosion other than pitting or crevice corrosion is not considered a problem in the proposed environment.

Conclusion:

Weld corrosion is not considered a problem for this system.

g Microbiologically Induced Corrosion (MIC)

MIC is normally observed at lower pH conditions and temperatures. Although microbes can live at very low pH, and probably high pH, as well as at 572°F, no reports of MIC in the proposed conditions have been reported.

Conclusion:

MIC is not considered a problem.

h Fatigue/Corrosion Fatigue

Corrosion fatigue is not expected to be a problem in these vessels.

Conclusions

Not expected to be a concern.

i Vapor Phase Corrosion

The vapor phase portion of the tank will be continually washed with condensing vapors while also being spattered with caustic.

Conclusion:

No vapor phase corrosion is anticipated.

j Erosion

Velocities within the vessel are expected to be sufficiently low in the recirculation system that erosion is not expected to occur.

Conclusion:

Not expected to be a concern.

k Galling of Moving Surfaces

Not applicable.

Conclusion:

Not applicable.

l Fretting/Wear

Not applicable.

Conclusion:

Not applicable.

m Galvanic Corrosion

Not applicable.

Conclusion:

Not applicable.

n Cavitation

Not applicable.

Conclusion:

Not applicable.

o Creep

Not applicable.

Conclusion:

Not applicable.

p Inadvertent Nitric Acid Addition

Higher chloride contents and higher temperatures usually require higher alloy materials. Nitrate ions inhibit the pitting and crevice corrosion of stainless alloys. Furthermore, nitric acid passivates these alloys; therefore, lower pH values brought about by increases in the nitric acid content of process fluid will not cause higher corrosion rates for these alloys. The upset condition that was most likely to occur is lowering of the pH of the vessel content by inadvertent addition of 0.5 M nitric acid. Lowering of pH may make a chloride-containing solution more likely to cause pitting of stainless alloys. Increasing the nitric acid content of the process fluid adds more of the pitting-inhibiting nitrate ion to the process fluid. In addition, adding the nitric acid solution to the stream will dilute the chloride content of the process fluid.

Conclusion:

The recommended materials will be able to withstand a plausible inadvertent addition of 0.5 M nitric acid.

PLANT ITEM MATERIAL SELECTION DATA SHEET**References:**

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2. Danielson, MJ & SG Pitman, 2000, *Corrosion Tests of 316L and Hastelloy C-22 in Simulated Tank Waste Solutions*, PNWD-3015 (BNFL-RPT-019, Rev 0), Pacific Northwest Laboratory, Richland WA.
3. Davis, JR (Ed), 1987, *Corrosion, Vol 13*, In "Metals Handbook", ASM International, Metals Park, OH 44073
4. Davis, JR, 1994, *Stainless Steels*, In ASM Metals Handbook, ASM International, Metals Park, OH 44073
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8. Sedriks, AJ, 1996, *Corrosion of Stainless Steels*, John Wiley & Sons, Inc., New York, NY 10158
9. Uhlig, HH, 1948, *Corrosion Handbook*, John Wiley & Sons, New York, NY 10158

Bibliography:

1. Jenkins, CF, 1998, *Performance of Evaporators in High Level Radioactive Chemical Waste Service*, Presented at Corrosion 98, NACE International, Houston TX 77084
2. Jones, RH (Ed.), 1992, *Stress-Corrosion Cracking*, ASM International, Metals Park, OH 44073
3. Smith, HD and MR Elmore, 1992, *Corrosion Studies of Carbon Steel under Impinging Jets of Simulated Slurries of Neutralized Current Acid Waste (NCAW) and Neutralized Cladding Removal Waste (NCRW)*, PNL-7816, Pacific Northwest Laboratory, Richland, Washington.
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OPERATING CONDITIONS

PROCESS CORROSION DATA SHEET

Component(s) (Name/ID #) Waste feed evaporator separator vessel (FEP-SEP-00001A/B)Facility PTFIn Black Cell? Yes

Chemicals	Unit ¹	Contract Max		Non-Routine		Notes
		Leach	No leach	Leach	No Leach	
Aluminum	g/l	7.25E+01	6.91E+01			
Chloride	g/l	2.65E+01	2.93E+01			
Fluoride	g/l	3.14E+01	3.49E+01			
Iron	g/l	1.62E+01	1.70E+01			
Nitrate	g/l	4.96E+02	5.34E+02			
Nitrite	g/l	1.44E+02	1.60E+02			
Phosphate	g/l	1.06E+02	1.15E+02			
Sulfate	g/l	5.56E+01	6.17E+01			
Mercury	g/l	5.66E-01	3.53E-01			
Carbonate	g/l	1.92E+02	2.01E+02			
Undissolved solids	wt%	3.0%	3.4%			Note 4
Other (NaMnO ₄ , Pb,...)	g/l					
Other	g/l					
pH	N/A					Note 3
Temperature	°F					Note 2

List of Organic Species:

Notes:

1. Concentrations less than 1×10^{-4} g/l do not need to be reported; list values to two significant digits max.
2. Topeation 77 °F to 122 °F.
boiling occurs at approximately 122 °F since the evaporator vessels are under vacuum.
3. pH approximately 13 to 14
4. Fluid in reboiler loop could contains solids as high as 8.9 wt%.

Assumptions:

PLANT ITEM MATERIAL SELECTION DATA SHEET**4.4.2 Waste Feed Evaporator Separator Vessel (FEP-SEP-00001A/B)****Routine Operations**

The FEP system contains two evaporator trains of the same capacity. Although the evaporator trains can operate simultaneously (each contains independent control logic), a single evaporator train has sufficient capacity to support the maximum production requirements of LAW and HLW glass. The evaporator product will have a liquid specific gravity of approximately 1.27, which corresponds to a Na concentration of 5 M, in order to optimize the operation of downstream processes, particularly the cesium ion exchange process system (CXP) and UFP system.

Solids within the evaporator recirculation loop are maintained in a suspended state by the waste feed evaporator recirculation pump (FEP-PMP-00009A or B). This pump recirculates waste at a high volumetric flowrate to limit fluid temperature rise when passing through the reboiler and subsequent flash evaporation. The evaporator feed pumps have variable speed drives. Separator vessel level is used to control feed rate to the evaporator. An increasing level in the separator vessel causes a decrease in feed rate while a decreasing level causes an increase in feed rate. At steady state, however, a relatively constant feed rate is maintained at an established boil-off rate. The buildup of solids on the separator vessel wall above the liquid level will be mitigated by an intermittent spray of recycled condensate.

Foaming tendencies in the separator vessel can be detected by elevations in pressure drop across the demister pads. Foaming in the separator vessel will be minimized by the addition of an antifoam agent from AFR-TK-00001. This addition is expected to be part of normal operations.

Non-Routine Operations that Could Affect Corrosion/Erosion

None identified.